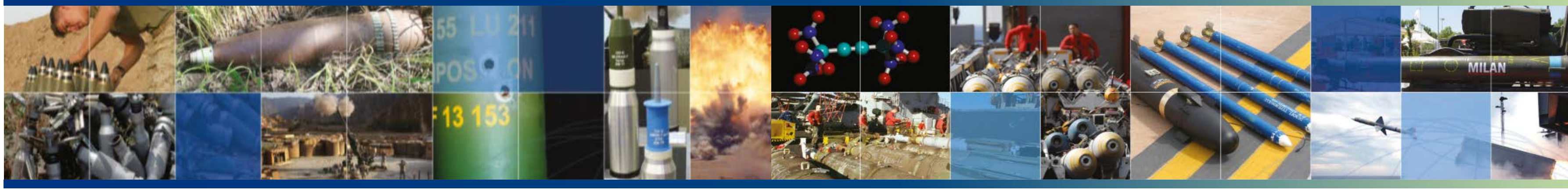
**Munitions Safety Information Analysis Center**

*Supporting Member Nations in the Enhancement of their Munitions Life Cycle Safety*




# MSIAC Workshop 2018:
## Improved Explosives and Munitions Risk Management

**IESS, San Diego, 6-9 August 2018**

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Improved Explosives and Munitions Risk Management
Granada, Spain | 10 - 14 September 2018

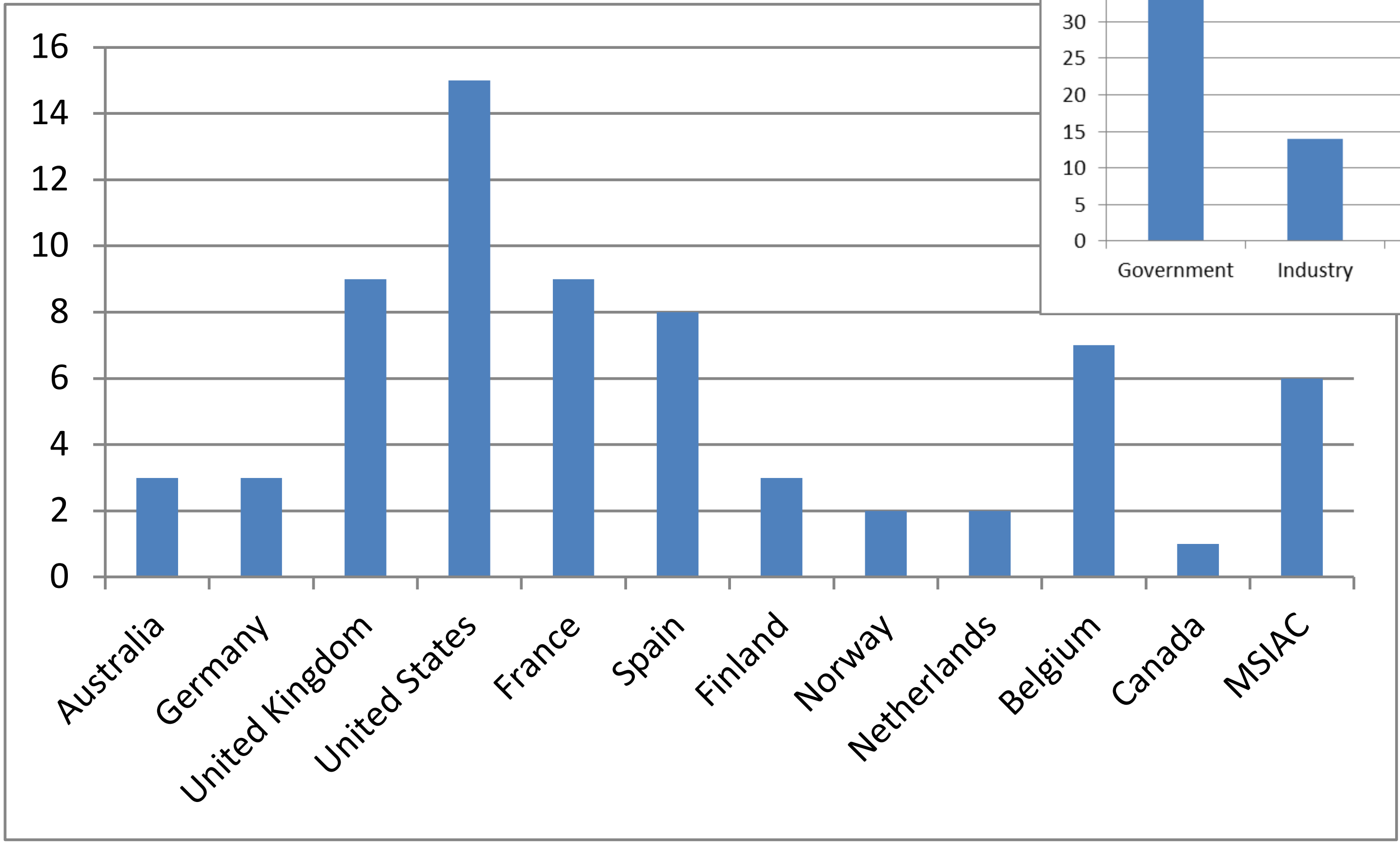
# IEMRM 2018

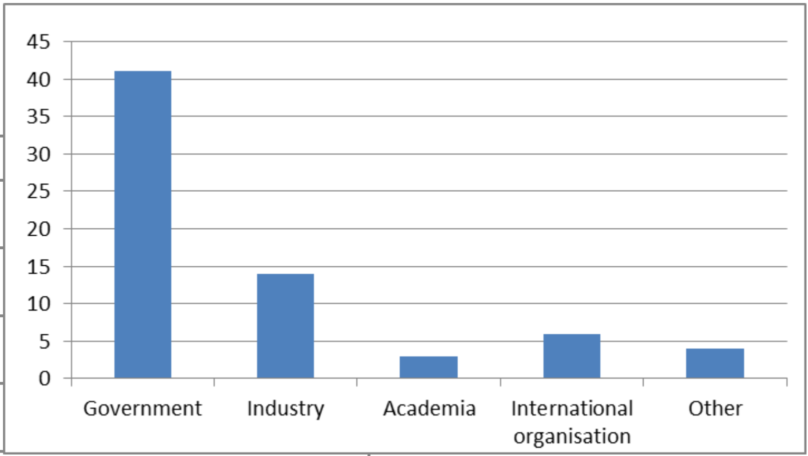

## Improved Explosives and Munitions Risk Management

Granada, Spain | 10 - 14 September 2018

# IEMRM 2018

- Unclassified workshop open at no cost to government, industry and academia representatives from all MSIAC member nations
- Limit of 70 participants almost reached



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# IEMRM 2018

- IEMRM workshop features:
  - Sun: Welcome reception
  - Mon: Plenary session
  - Tue – Thu: Parallel sessions (focus areas) and plenary sessions (back briefs)
  - Tue: Workshop dinner
  - Wed: Visit to GDELS
  - Fri: Conclusions

- IEMRM preparations:
  - 15 MSIAC papers and/or presentations
  - 34 papers and/or presentations from participants
  - MSIAC Sharefile repository with papers and references
  - Webinar
  - Site survey

Improved Explosives and
Munitions Risk Management
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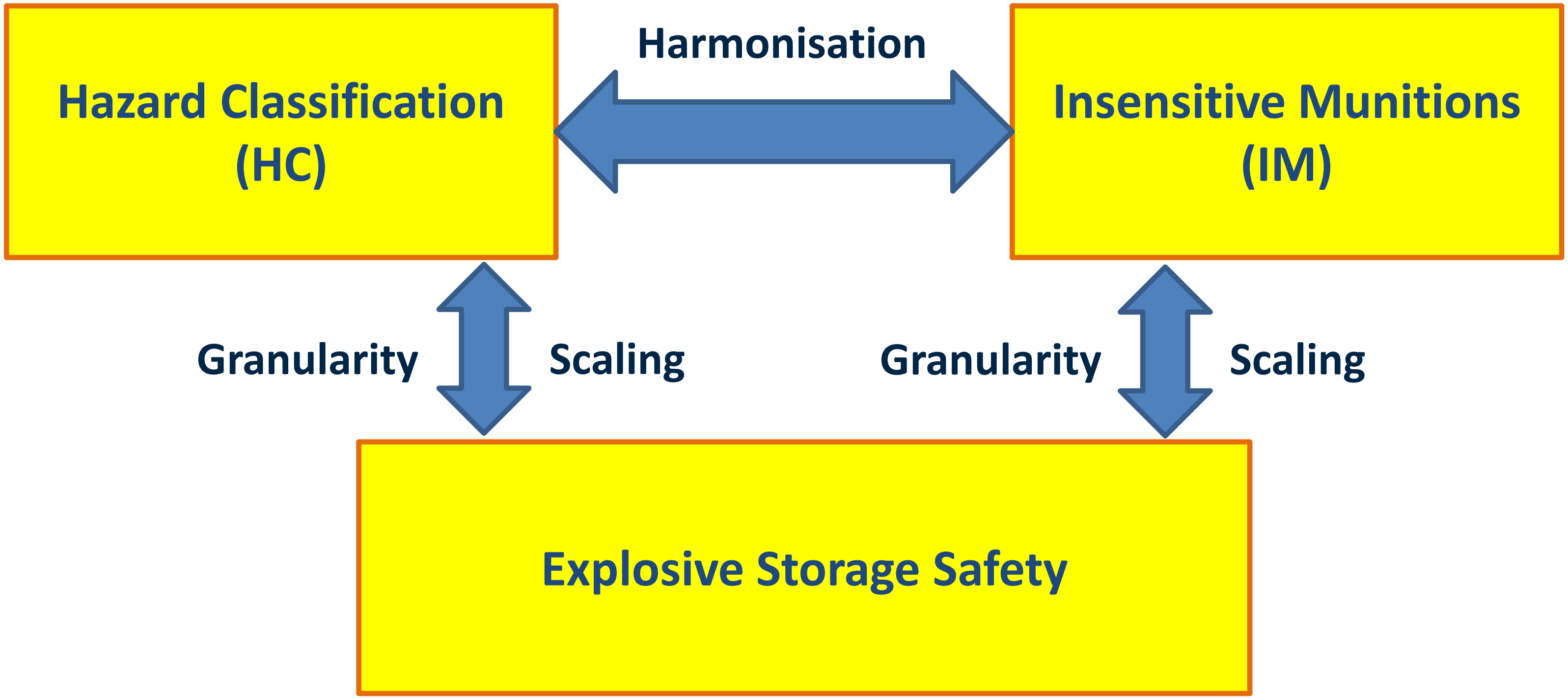
# Improved Explosives and Munitions Risk Management

*This workshop seeks to exploit an improved understanding of munitions vulnerability and consequences to deliver improvements in munitions risk management*



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# Objectives

- **Support** the IM and HC harmonization initiative
  - Identify how response descriptors can be introduced in HC testing
  - Identify whether there's a need for a revised definition of Hazard Divisions (HD) and Storage sub Divisions (SsD)
- **Develop** improved methods for explosives and munitions risk management
  - Exploit results from small- and full-scale testing
  - Manage risk with sufficient detail and granularity
  - Realize benefits of IM
  - Efficiently manage munitions presenting the greatest hazard
- **Recommend** improved methods for explosives and munitions safety risk standards
  - Ensuring they reflect the changing nature of the munitions stockpile
  - Balancing complexity versus ease of user application

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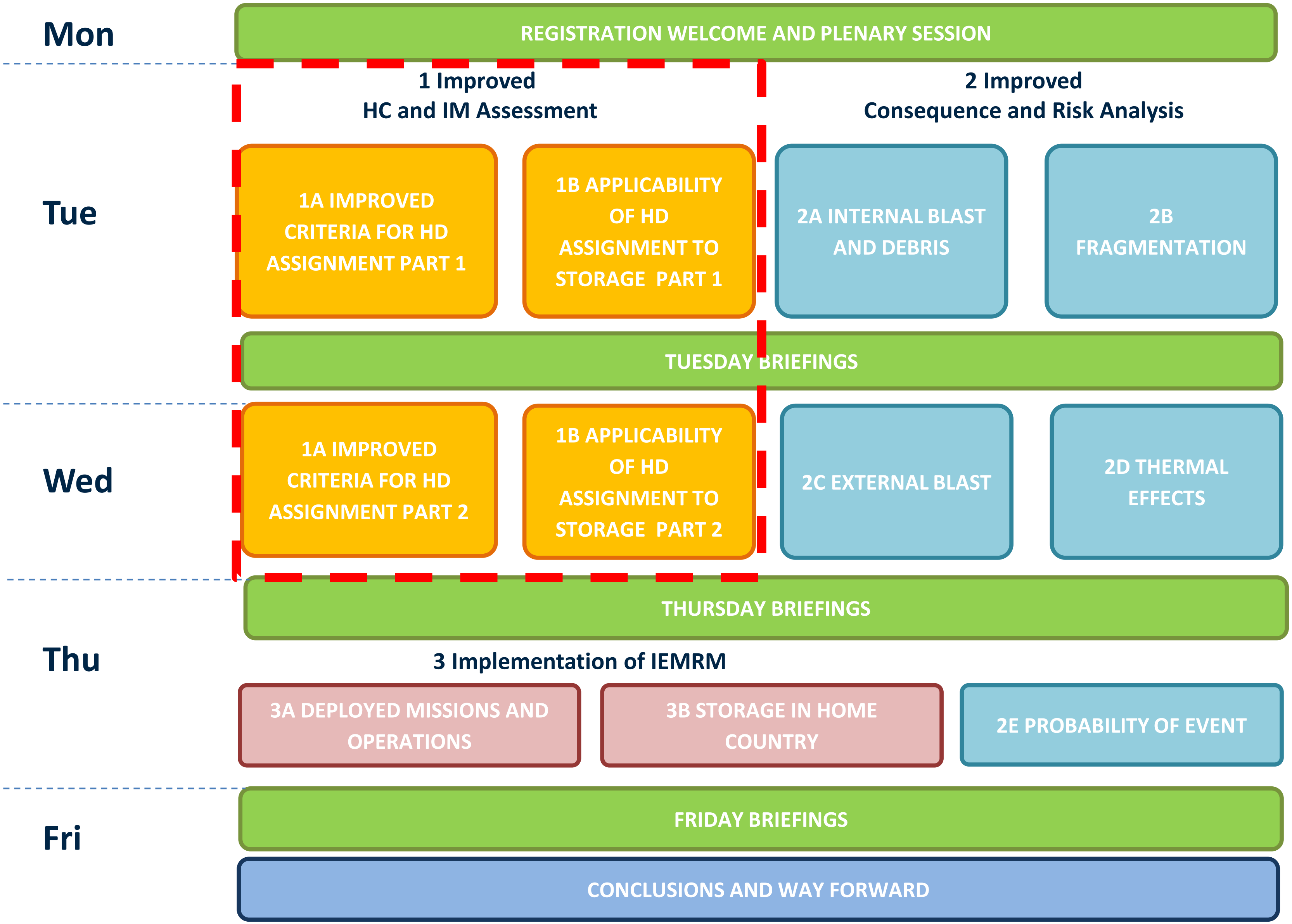
# Workshop structure

| Day | 1 Improved HC and IM Assessment | | 2 Improved Consequence and Risk Analysis | |
|---|---|---|---|---|
| Mon | REGISTRATION WELCOME AND PLENARY SESSION | | | |
| Tue | 1A IMPROVED CRITERIA FOR HD ASSIGNMENT PART 1 | 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE PART 1 | 2A INTERNAL BLAST AND DEBRIS | 2B FRAGMENTATION |
| | TUESDAY BRIEFINGS | | | |
| Wed | 1A IMPROVED CRITERIA FOR HD ASSIGNMENT PART 2 | 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE PART 2 | 2C EXTERNAL BLAST | 2D THERMAL EFFECTS |
| Thu | THURSDAY BRIEFINGS | | | |
| | **3 Implementation of IEMRM** | | | |
| | 3A DEPLOYED MISSIONS AND OPERATIONS | 3B STORAGE IN HOME COUNTRY | 2E PROBABILITY OF EVENT | |
| Fri | FRIDAY BRIEFINGS | | | |
| | CONCLUSIONS AND WAY FORWARD | | | |

# Workshop structure



# Improved criteria for HD assignment



Current HC system loosely defines explosive effects

Differences in Hazard Divisions (HD) between nations possible

| | Munitions Response |
|---|---|
| I | Detonation |
| II | Partial Detonation |
| III | Explosion |
| IV | Deflagration |
| V | Burn |
| VI | No Reaction |

*IM response levels*

**Q:** Can IM test responses be introduced into HC assessment* and what would be the assessment criteria?

**this was already done for test series 7 used to classify HD1.6*

# Improved criteria for HD assignment

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| Response Level | Energetic Materials (EM) | Case | Blast | Fragment or EM projection | Other |
|---|---|---|---|---|---|
| Type I (detonation) | Prompt consumption of all EM once the reaction starts | **(P) Rapid plastic deformation of the metal casing contacting the EM with extensive high shear rate fragmentation** | **(P) Shock wave with magnitude & timescale = to a calculated value or measured value from a calibration test** | Perforation, fragmentation and/or plastic deformation of witness plates | Ground craters of a size corresponding to the amount of EM in the munition |
| Type II (partial detonation) | | **(P) Rapid plastic deformation of some, but not all, of the metal casing contacting the EM with extensive high shear rate fragmentation** | **(P) Shock wave with magnitude & timescale < than that of a calculated value or measured value from a calibration test** Damage to neighbouring structures | Perforation, plastic deformation and/or fragmentation of adjacent metal plates. Scattered burned or unburned EM. | Ground craters of a size corresponding to the amount of EM that detonated. |
| Type III (explosion) | **(P) Rapid combustion of some or all of the EM once the munition reaction starts** | **(P) Extensive fracture of metal casings with no evidence of high shear rate fragmentation resulting in larger and fewer fragments than observed from purposely detonated calibration tests** | Observation or measurement of a pressure wave throughout the test arena with peak magnitude << than and significantly longer duration that of a measured value from a calibration test | Witness plate damage. Significant long distance scattering of burning or unburned EM. | Ground craters. |
| Type IV (deflagration) | **(P) Combustion of some or all of the EM** | **(P) Rupture of casings resulting in a few large pieces that might include enclosures or attachments.** | Some evidence of pressure in the test arena which may vary in time or space. | **(P) At least one piece (casing, enclosure or attachment) travels beyond 15m with an energy level > 20J based on the distance/mass relationship used for HC[1].** Significant scattered burning or unburned EM, generally beyond 15 m. | **(P) There is no primary evidence of a more severe reaction and there is evidence of thrust capable of propelling the munition beyond 15m.** Longer reaction time than would be expected in a Type III reaction. |
| Type V (burn) | **(P) Low pressure burn of some or all of the EM** | **(P) The casing may rupture resulting in a few large pieces that might include enclosures or attachments.** | Some evidence of insignificant pressure in the test arena. | **(P) No item (casing, enclosure, attachment or EM) travels beyond 15m with an energy level > 20J based on the distance/mass relationship used for HC[1].** **(P) A small amount of burning or unburned EM relative to the total amount in the munition may be scattered, generally within 15m but no further than 30m.** | **(P) No evidence of thrust capable of propelling the munition beyond 15m.** For a rocket motor a significantly longer reaction time than if initiated in its design mode. |
| Type VI (no reaction) | **(P) No reaction of the EM without a continued external stimulus.** **(P) Recovery of all or most of the unreacted EM with no indication of a sustained combustion.** | **(P) No fragmentation of the casing or packaging greater than that from a comparable inert test item.** | None | None | None |

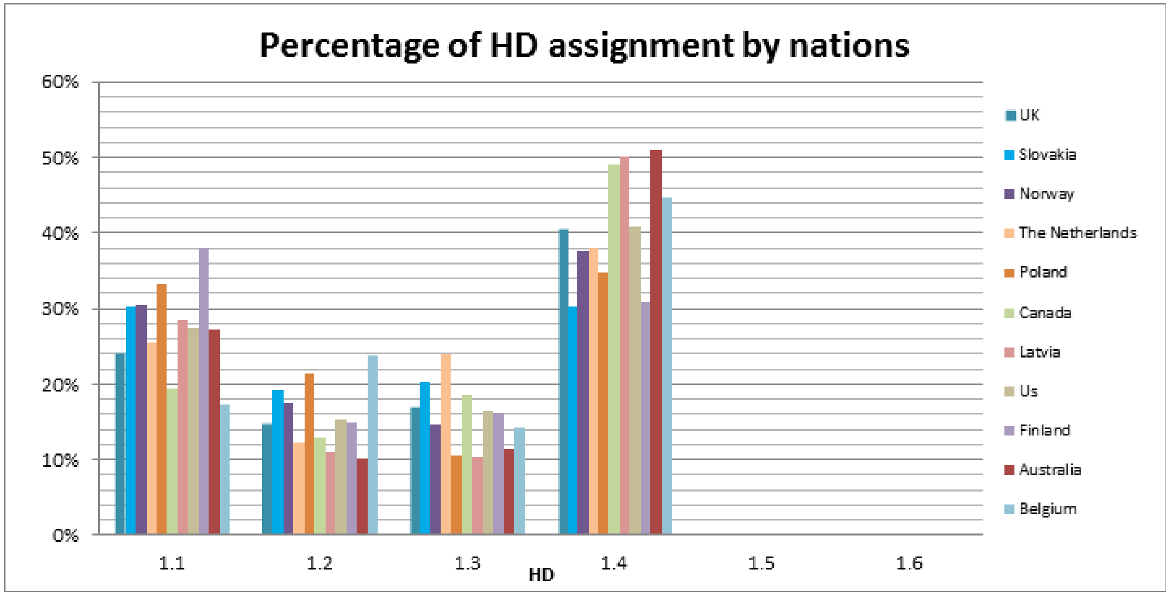
*Primary evidence* (P), shown in Bold text, would almost always be observed and would be definitive of the reaction type.
*Secondary evidence* could be observed, but its lack would not preclude that reaction type.

Note: (1) Fragment energy relationship shown in the Figure I-1

# Improved criteria for HD assignment

Observations from MSIAC HC database

- HD1.5 and 1.6 absent
- SsD1.2.3 only 61 assignments





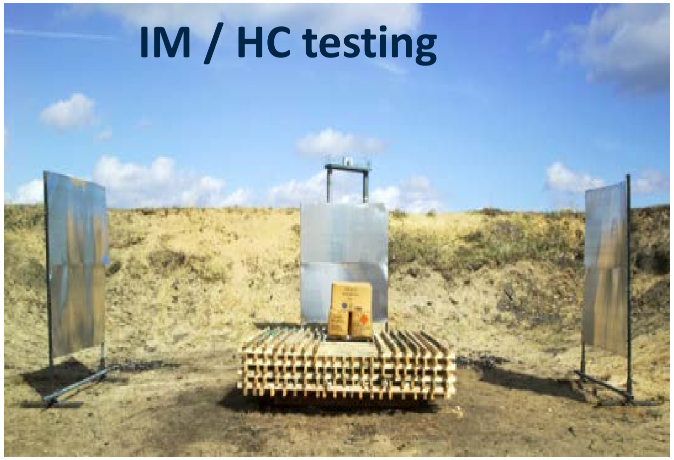
*Study of International Hazard Classification, Leroy (2017)*

Current HD & SsD not an ideal representation of munitions stockpile

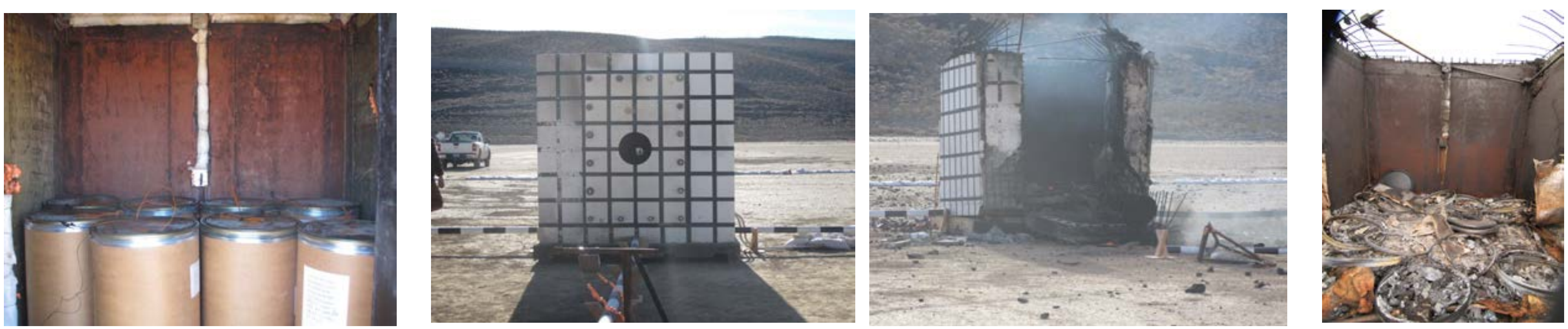
**Q:** Is it necessary to revise the definitions of HD and SsD and what would be the implications?

# Applicability of HD to storage

HC (UN orange book) for transport also adopted for storage

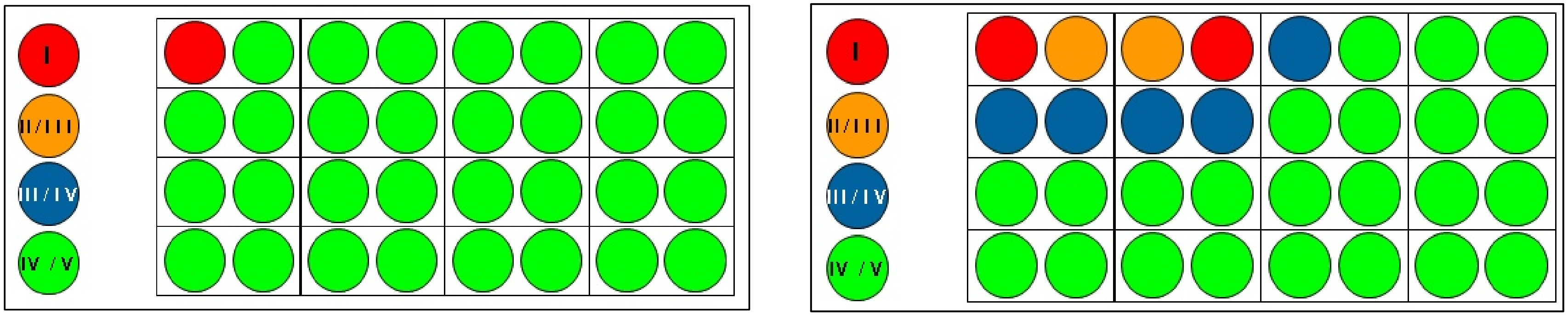



Scaling
Confinement

*Confinement example: US propellant testing in reinforced concrete magazines, Farmer, et al. 2015*

# Applicability of HD to storage




*Scaling example: 105 mm HE IM shells, Edwards (2011), single shell detonation (left), two shell detonation (right)*

**Q:** Can we develop improved guidance to clarify the applicability of HC assessments?

**Q:** What complementary information (related to scale and confinement) is needed to make a reliable estimate of munitions response in storage conditions?

**Q:** What information from the explosive (storage) safety community is needed?

**Q:** What is a sufficient number of test repetitions?

**Q:** Are there best practices?

# Workshop structure

**Mon**

- REGISTRATION WELCOME AND PLENARY SESSION

**Tue**

1 Improved HC and IM Assessment

- 1A IMPROVED CRITERIA FOR HD ASSIGNMENT PART 1
- 1B APPLICABILITY OF HD ASSIGNMENT TO STORAGE PART 1

2 Improved Consequence and Risk Analysis

- 2A INTERNAL BLAST AND DEBRIS
- 2B FRAGMENTATION

- TUESDAY BRIEFINGS

**Wed**

- 1A IMPROVED CRITERIA FOR HD ASSIGNMENT PART 2
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- THURSDAY BRIEFINGS

3 Implementation of IEMRM

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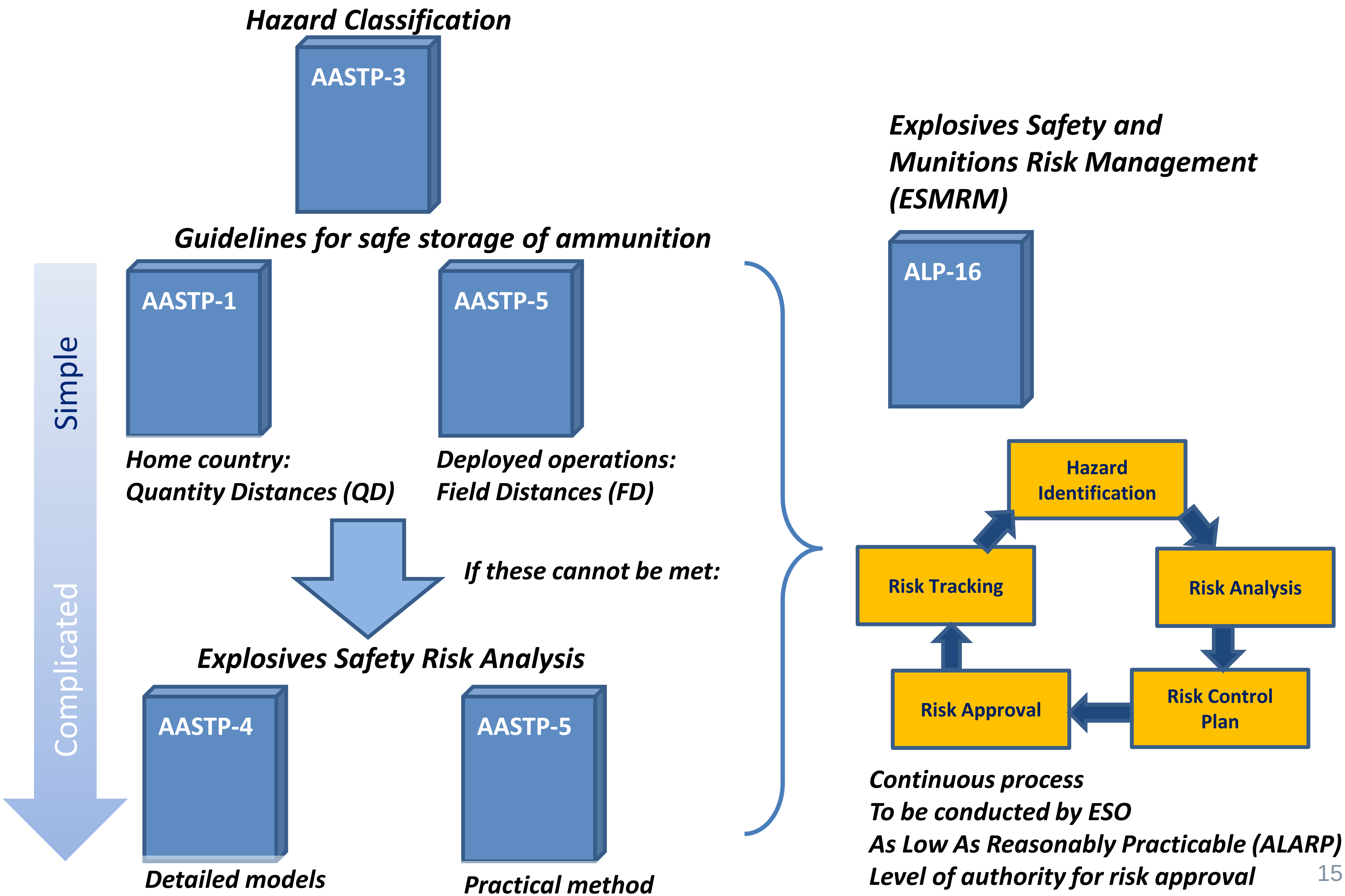
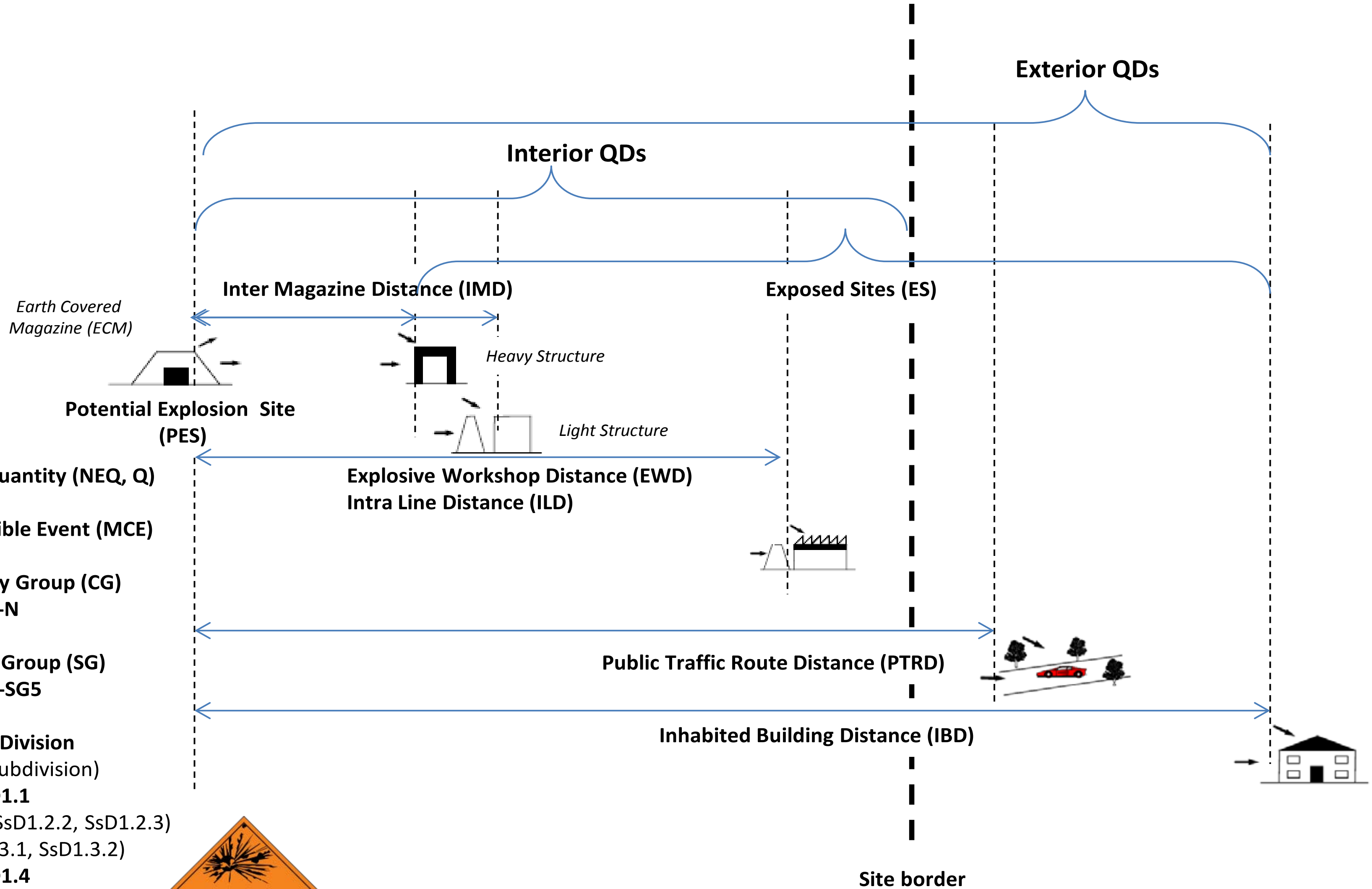
# Current risk management



# Quantity Distances




**Net Explosive Quantity (NEQ, Q)**

**Maximum Credible Event (MCE)**

**Compatibility Group (CG)**
**A-N**

**Sensitivity Group (SG)**
**SG1-SG5**

**Hazard Division**
(Storage Subdivision)
**HD1.1**
**HD1.2** (SsD1.2.1, SsD1.2.2, SsD1.2.3)
**HD1.3** (SsD1.3.1, SsD1.3.2)
**HD1.4**
**HD1.5**
**HD1.6**

# Consequence and risk analysis

Current models primarily available for (mass) detonations

Benefits of less violent munitions responses cannot always be exploited

| **Munitions response descriptors (AOP-39)** | | **Models available for consequence and risk analysis, e.g. AASTP-4?** |
|---|---|---|
| **I** | Detonation | Yes |
| **II** | Partial Detonation | Yes/No (fraction that will detonate uncertain) |
| **III** | Explosion | No |
| **IV** | Deflagration | No |
| **V** | Burn | Yes |
| **VI** | No Reaction | NA |

**Q:** What experimental data and models are required to quantify consequences and risks based on the response descriptors, in particular for Deflagration (type IV) and Explosion (type III)?

# Physical effects & probability

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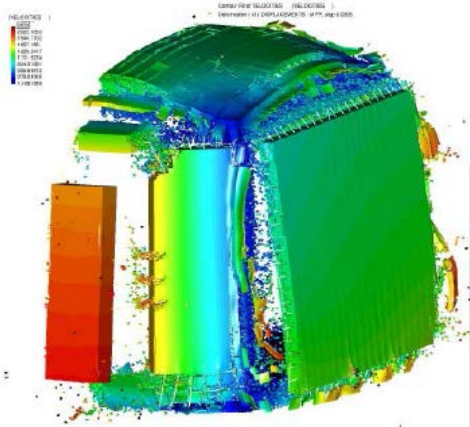
## Various sessions on:

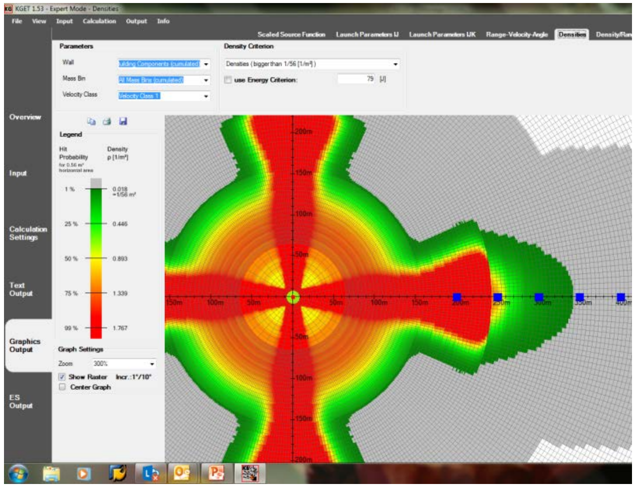
- Internal blast and debris
- Fragmentation
- External blast
- Thermal effects
- Probability of event



*Detonation in RC magazine (Applied Simulations, Inc)*

*High speed frame from Kasun test* (Grønsten)

*840 g steel fragment from a M107 155 mm artillery shell that reached 1824 m after a sub-detonative response. (Baker)*



*Klotz Group Engineering Tool v 1.5.3*

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CONCLUSIONS AND WAY FORWARD

# Implementation of IEMRM

Increased **granularity and detail** → more complex **QD tables** and **consequence and risk analysis** methods.

- In some areas this is very necessary, think about AASTP-5 where all munitions are to be aggregated as HD1.1. As a result benefits of any HD other than HD1.1 are currently not seen.
- In other areas (AASTP-1, already 100 pages of QD tables in current version) standards may become difficult to use. What is still acceptable?

Alternate approach: introduction of **computer-based tools**

- Easier application, less prone to error
- But also leads to a dependency on IT equipment which may be an issue e.g. during operations. Is this acceptable?

# Implementation of IEMRM

**Munition-specific** consequence and risk analysis

- Improves reliability of the results
- But limits range of applicability. Is this acceptable?

Development of **holistic approach**

- Cost and benefits of simplistic and conservative assessment methods versus more detailed quantitative assessment methods.
- Most suitable approach dependent on the lifecycle phase

**Exploitation** of smaller QDs and risks has issues:

- Reducing distances is often not possible (stationary infrastructure).
- Increasing quantities is also often not possible (in case of fully loaded storage buildings).

# Conclusions

## The envisaged results of the workshop are:

- Revised approach to munitions hazards and risks in light of development and introduction of IM
- Improved methods for consequence and risk analysis
- Improved understanding of the true nature of hazards and risks and how this can improve ownership and associated costs

## See related presentation on Wednesday:

“Explosion Effects and Consequences from Detonations and Less Violent Munitions Response”

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# Questions?

Improved Explosives and
Munitions Risk Management

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